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LSDS Large-Scale Distributed Systems Group

Spotnik

Designing Distributed Machine Learning for Transient Cloud Resources

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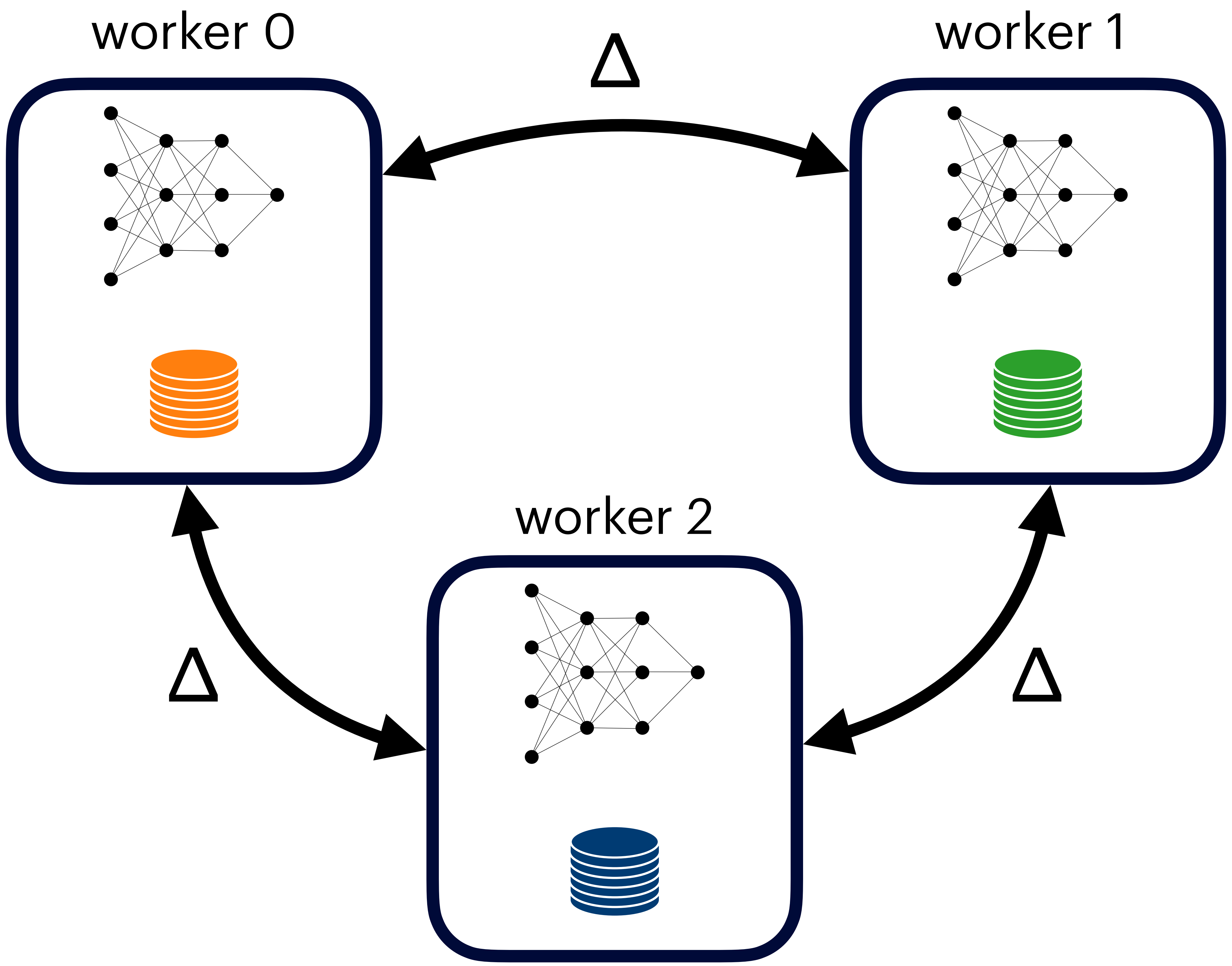
Distributed ML

Train a machine learning model



Distributed ML

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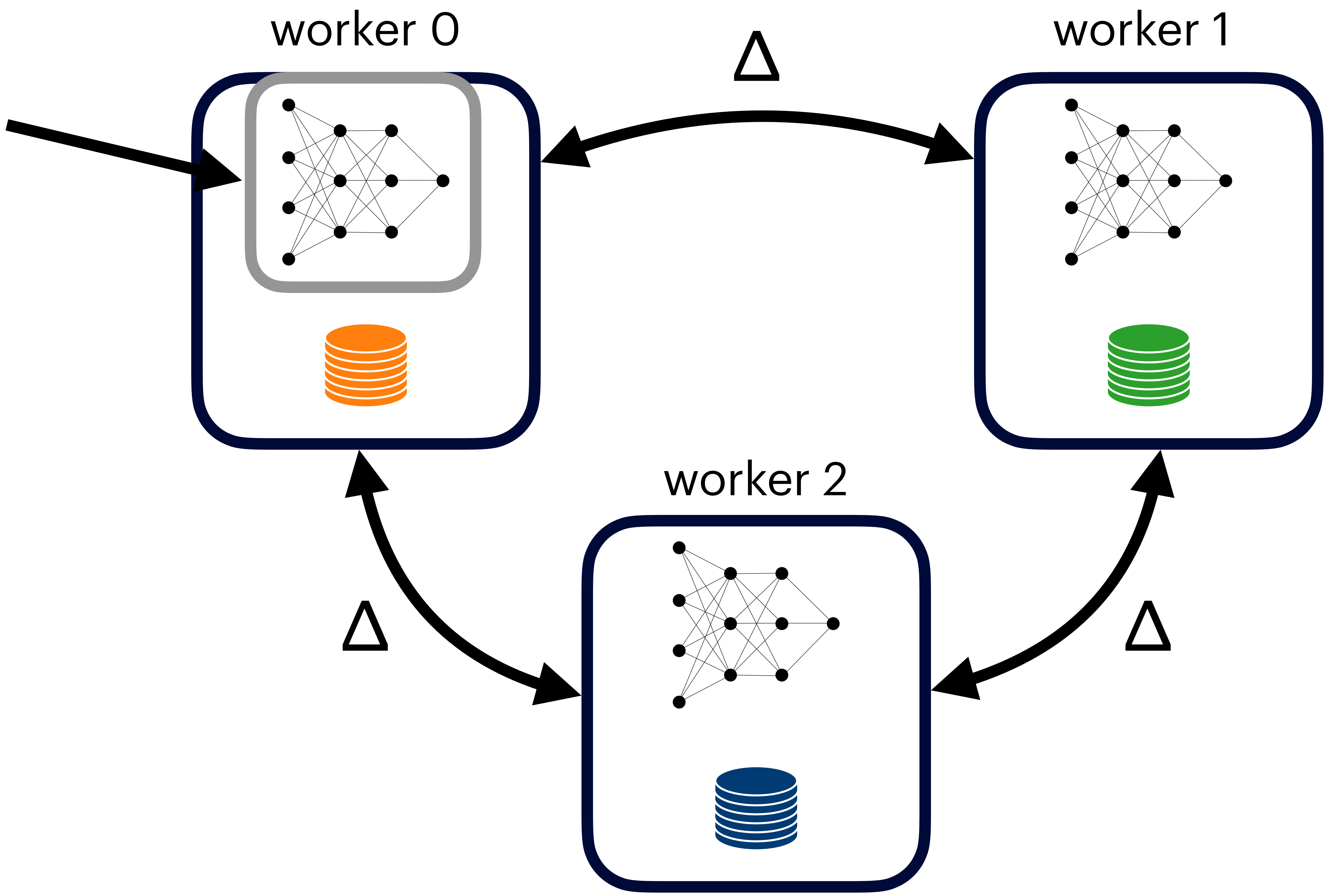
Learn a model



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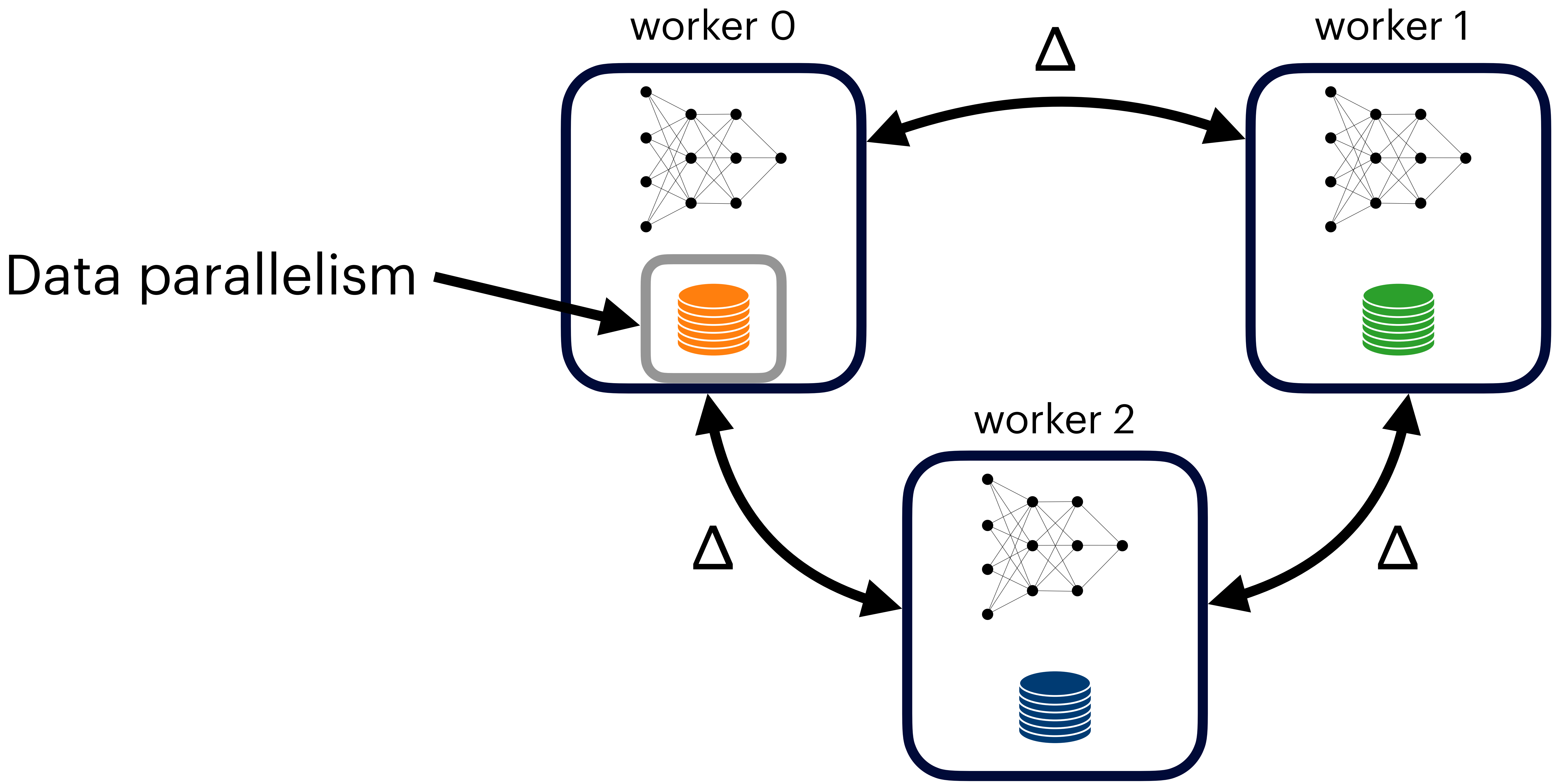

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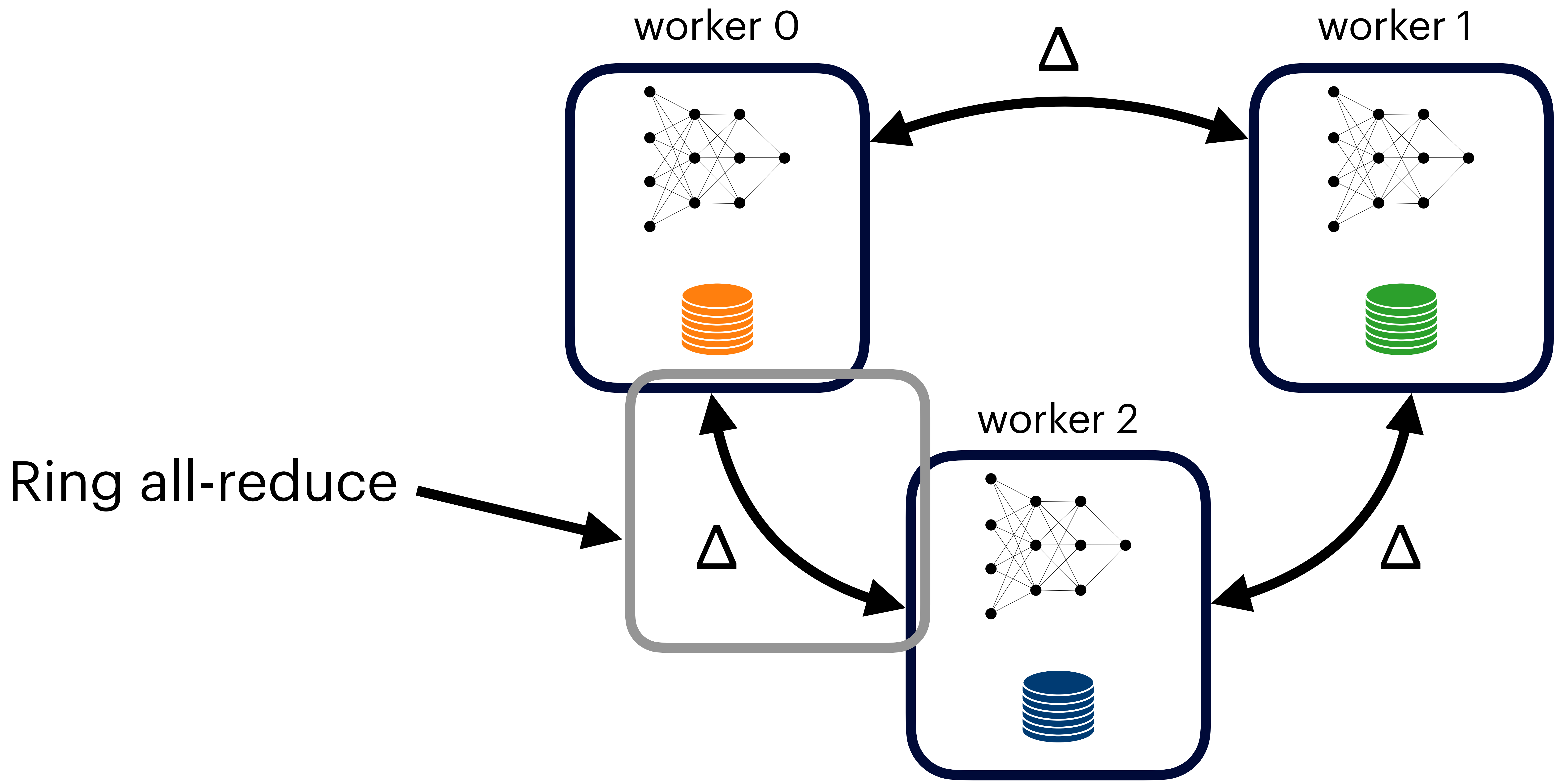


Challenges of distributed ML

- Distributed ML is **resource-hungry**
- Accelerated resources are **expensive**

Example Megatron-LM[3]

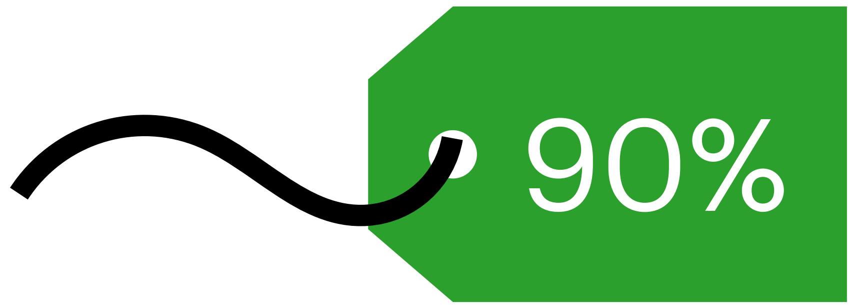
- Training of BERT-like model
- 512 V100 GPUs
- One epoch (68,507 iterations) takes 2.1 days
  - Cost on Azure: $92,613

[3]Shoeybi, Mohammad, et al. Megatron-LM: Training multi-billion parameter language models using gpu model parallelism, 2017

Transient cloud resources

- Examples: AWS Spot instances, Azure Spot VMs
- Follows the law of a free market
- Revocations
  - Notifications

- Economic incentive
  - Offers a **cost reduction** of up to 90%[1]

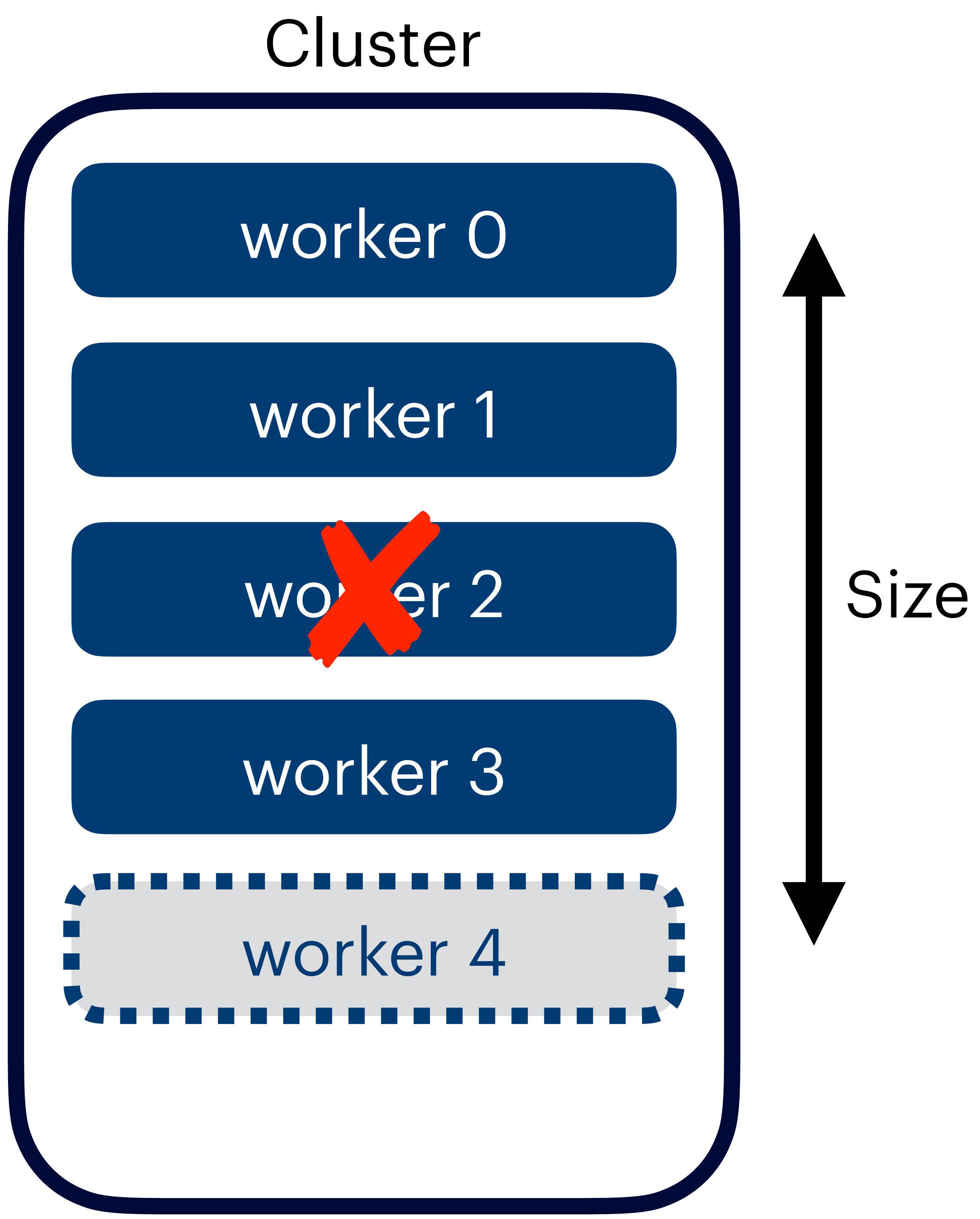


A Megatron-LM epoch would drop from $92,613 to $15,152

[1]https://azure.microsoft.com/en-us/pricing/spot/

Implications of transient resources

- New workers become available or old workers get revoked
  - ➙ System must cope with disappearing resources
- Changes can happen at any time
  - ➙ System must ensure consistency of updates



Implications of transient resources

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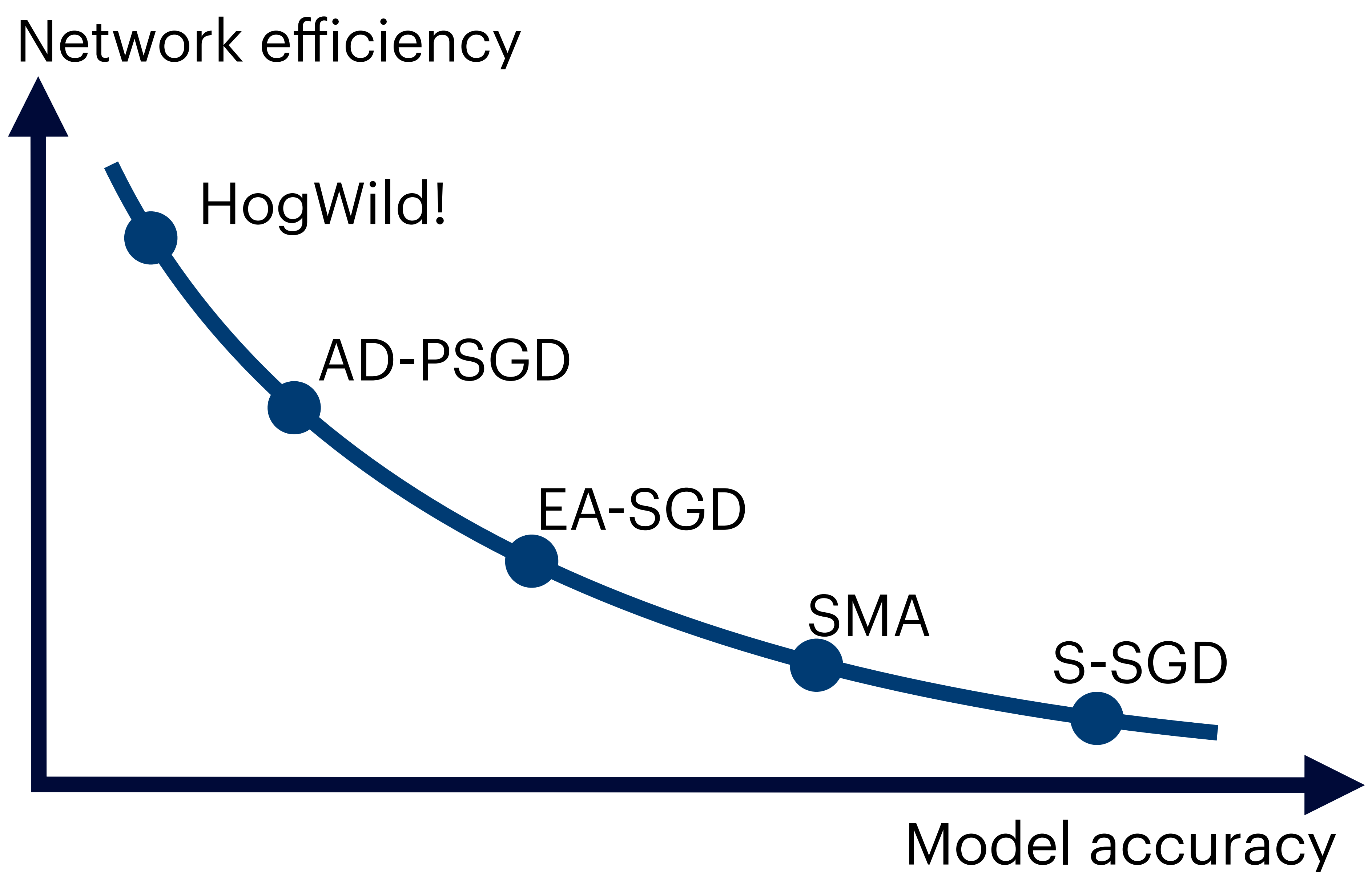
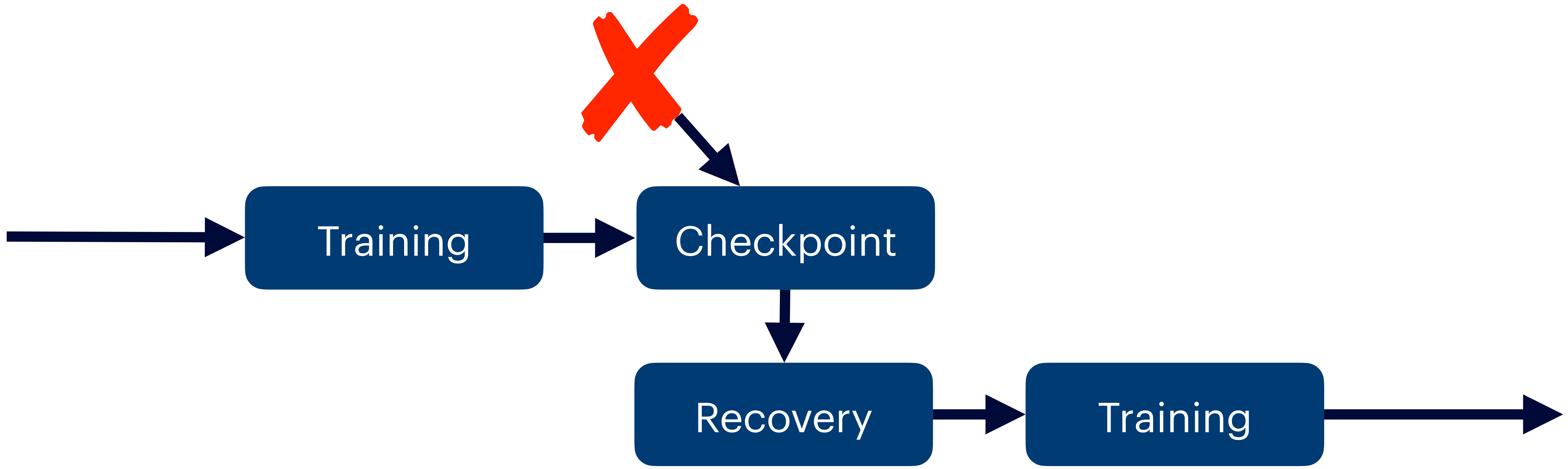
- Cluster sizes are unknown beforehand
  - ➙ System must adapt to different conditions



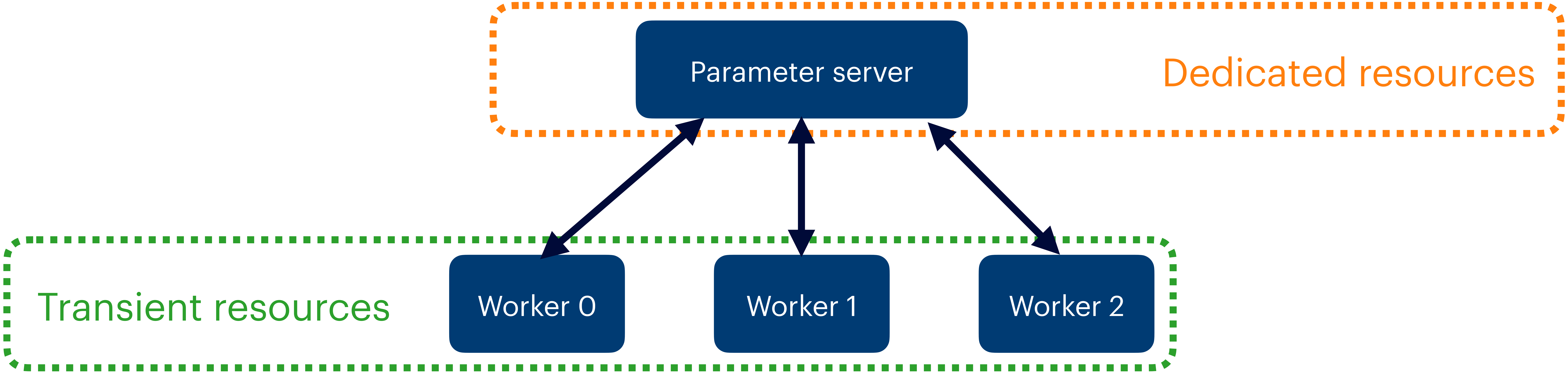
Current approach: Checkpoint & recovery

- Tensorflow and Pytorch
- Changes to the cluster are not considered
- Recovery takes about 20 seconds with ResNet50 and ImageNet



Current approaches: Hybrid

- Mix dedicated resources with transient resources
- Proteus[2]: Placement of parameter server on dedicated resources so that the training state is save



[2]Harlap et al. Proteus: agile ML elasticity through tiered reliability in dynamic re- source markets. EuroSys, 2017

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Challenges	Solutions
Workers become available or get revoked	**Reuse communication channels** for synchronisation to repair the cluster
Changes can happen at any time	Ensure **atomic model updates** by waiting for all synchronisations to finish first
Cluster sizes are unknown beforehand	**Change the synchronisation strategy** based on the number of workers

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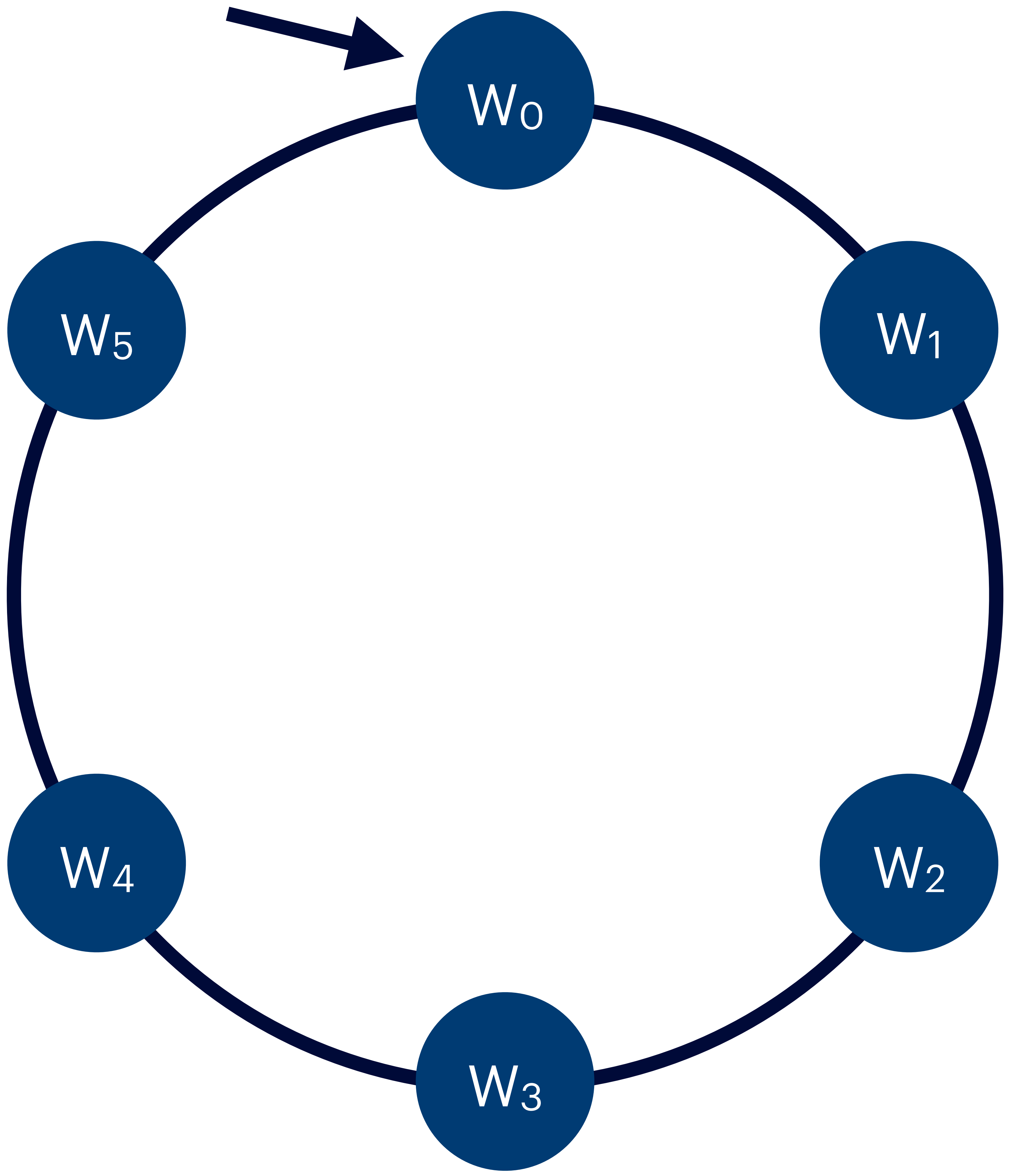
Revocation recovery algorithm

- Handle revocations within a ring topology
- Number of total messages is bounded by $O(N \cdot K)$ messages
  - K is the number of simultaneous revocations
  - N is the number of workers

  → Scale to many transient resources
- No reliance on revocation notifications

Revocation recovery algorithm

Repairing a broken all-reduce ring



Worker	Membership
0	[0, 1, 2, 3, 4, 5]
1	[0, 1, 2, 3, 4, 5]
2	[0, 1, 2, 3, 4, 5]
3	[0, 1, 2, 3, 4, 5]
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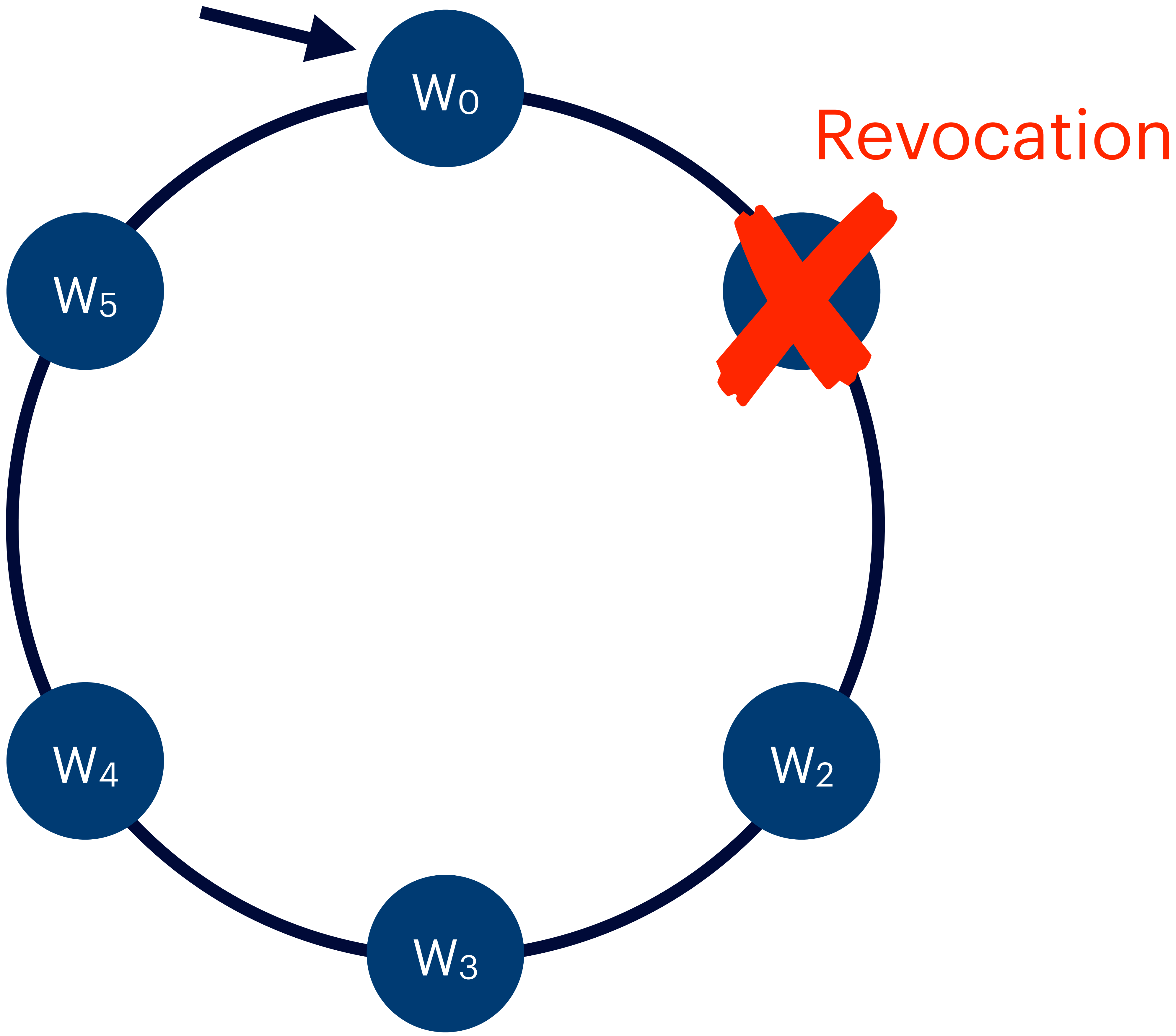
Revocation recovery algorithm

Repairing a broken all-reduce ring

Reconcile



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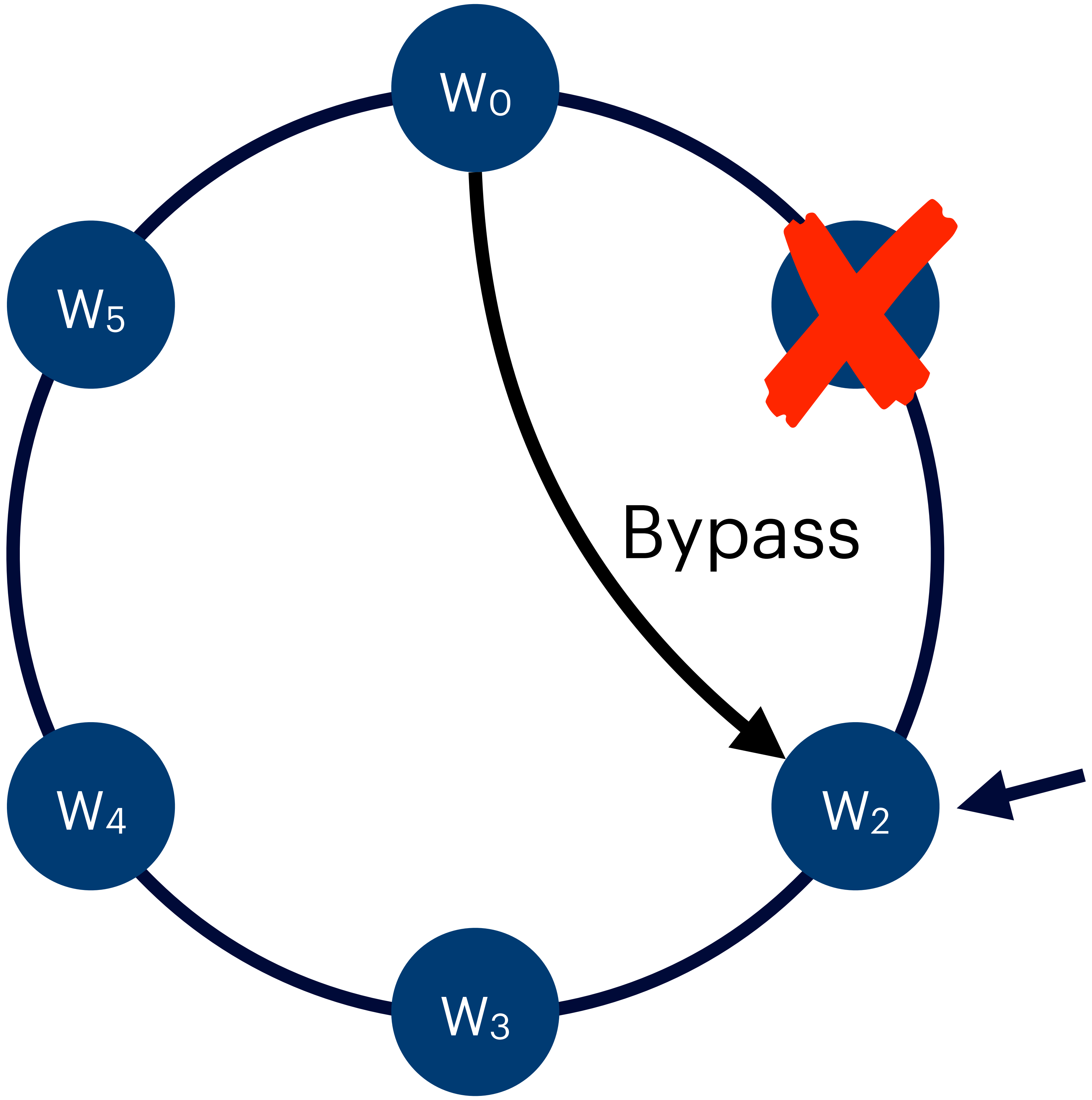

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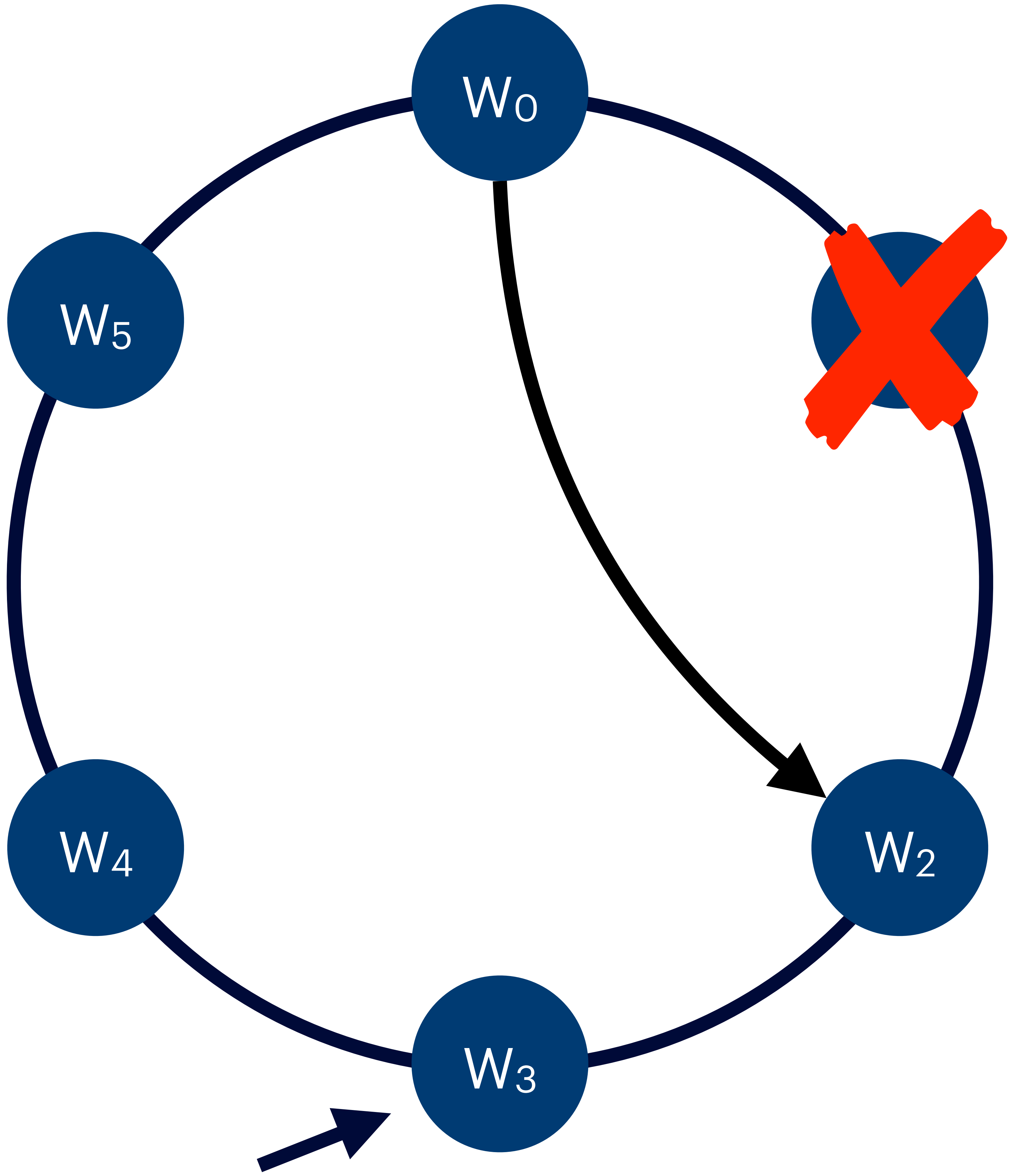

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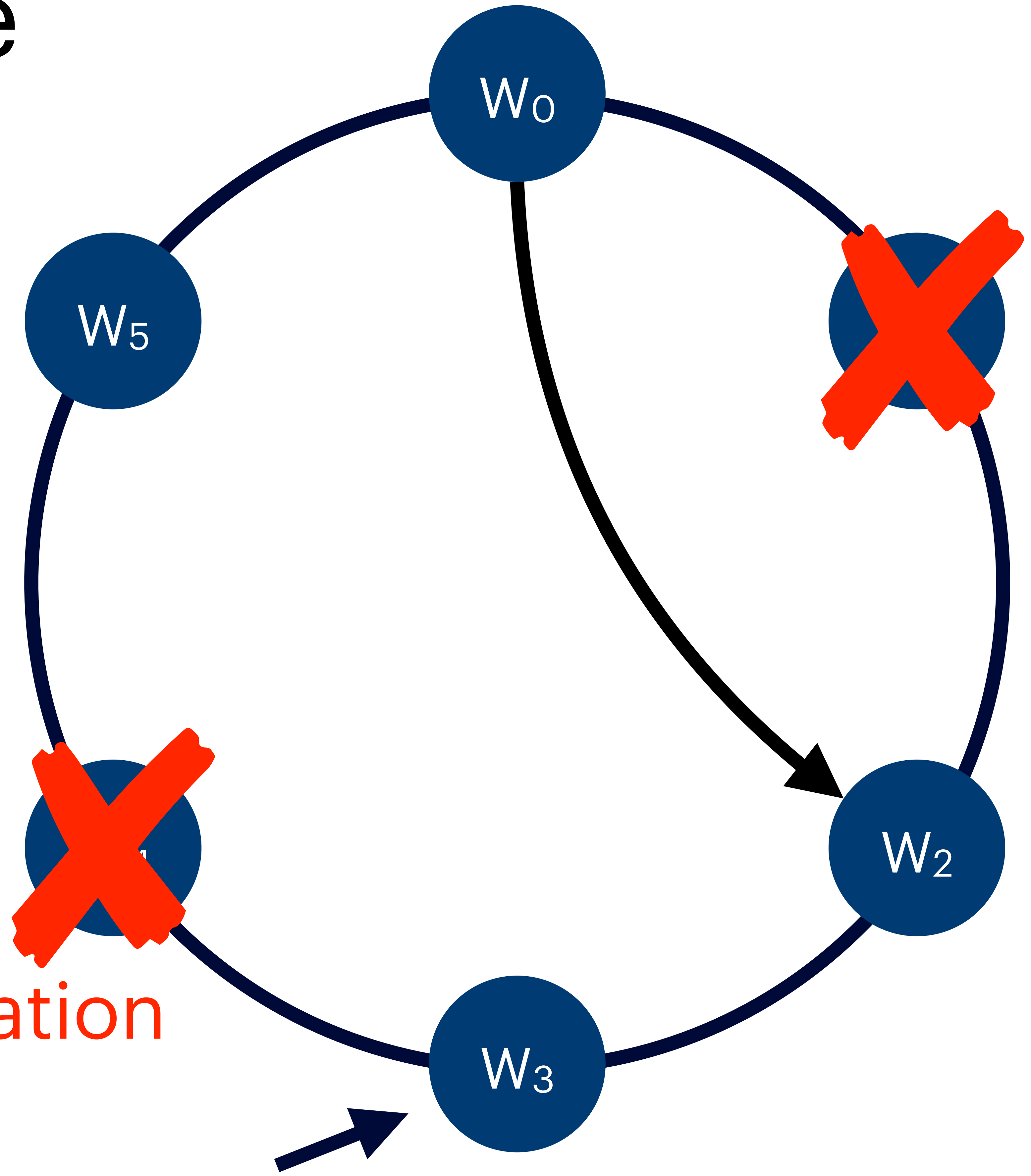

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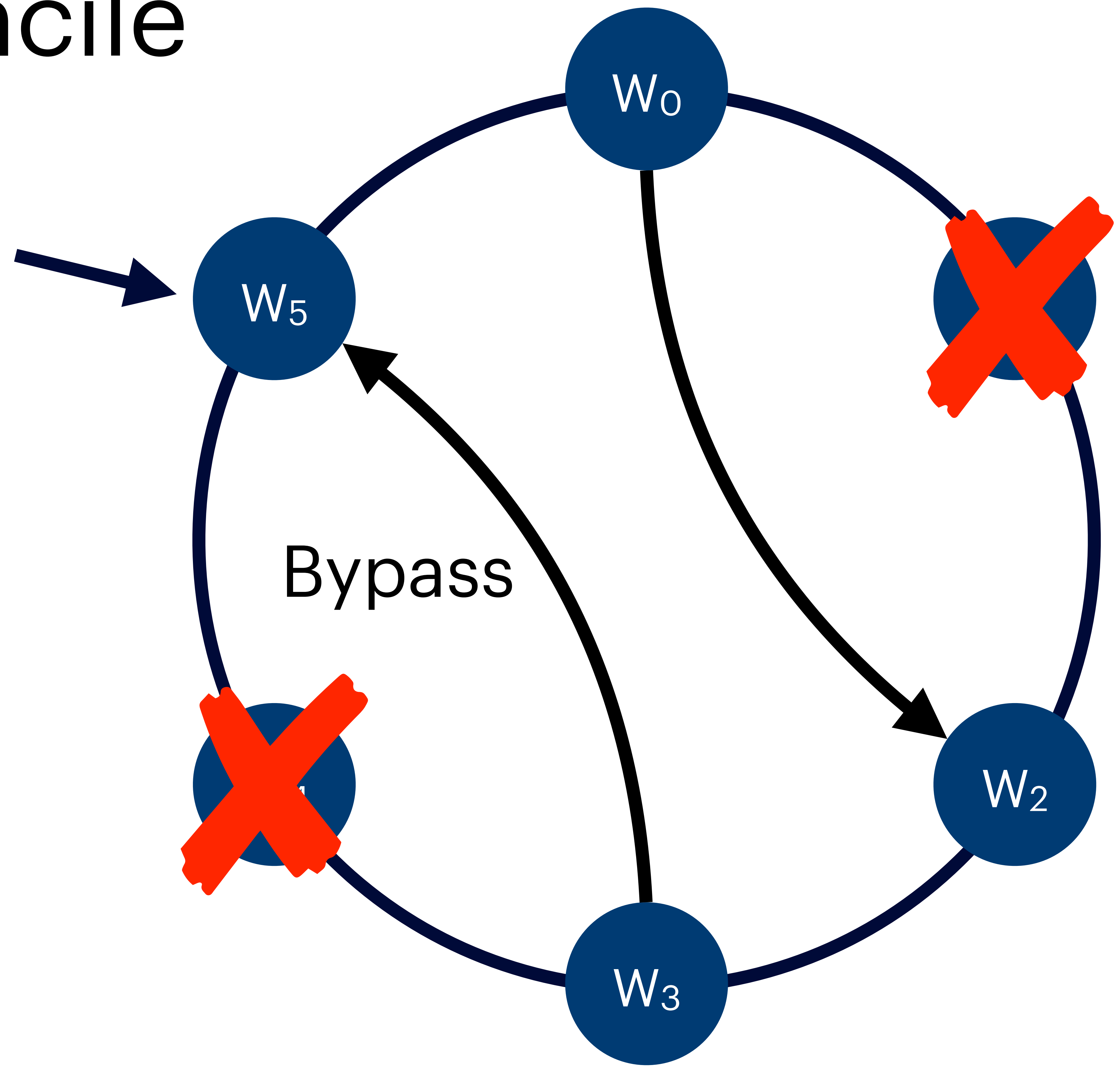

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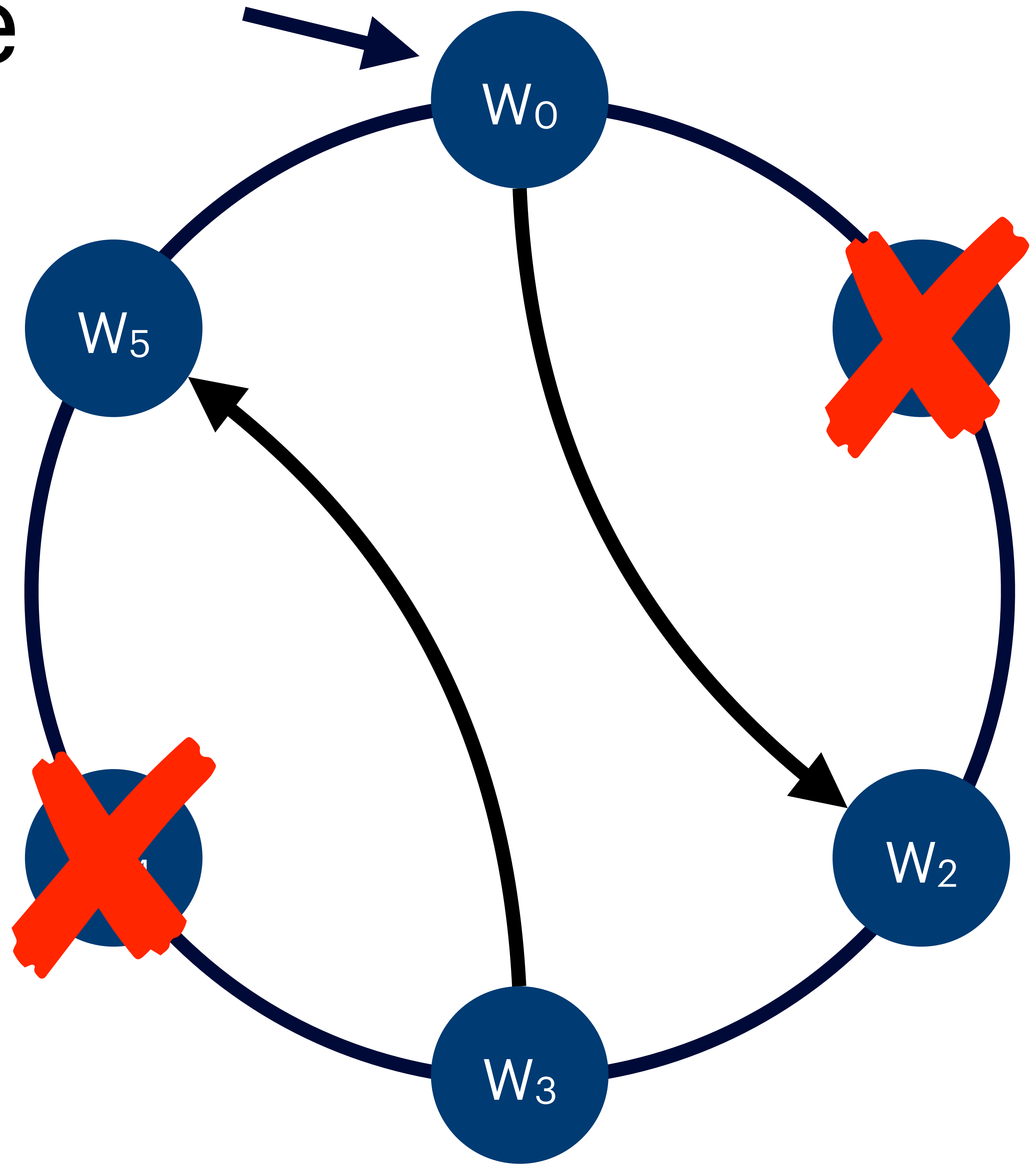

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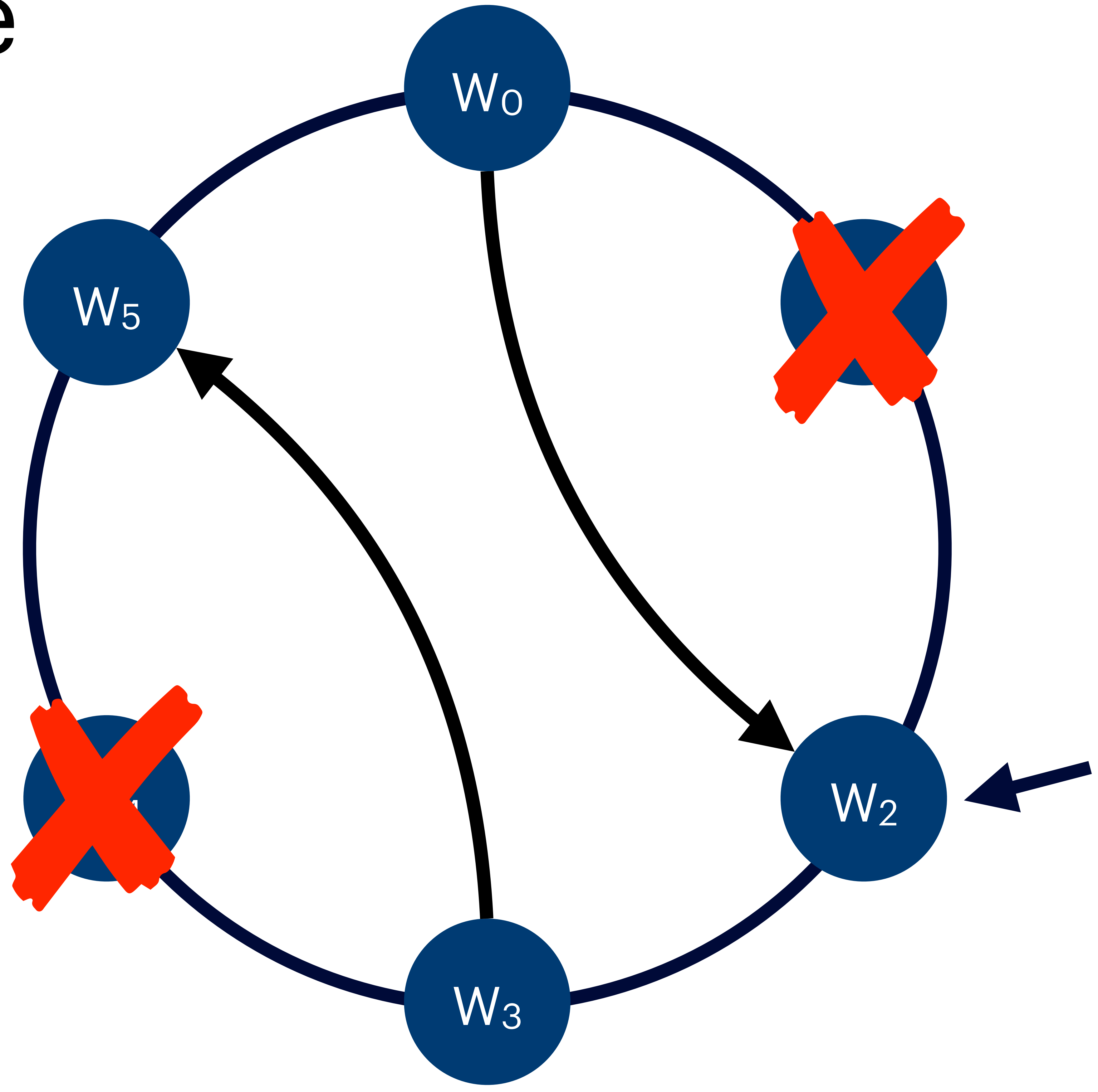

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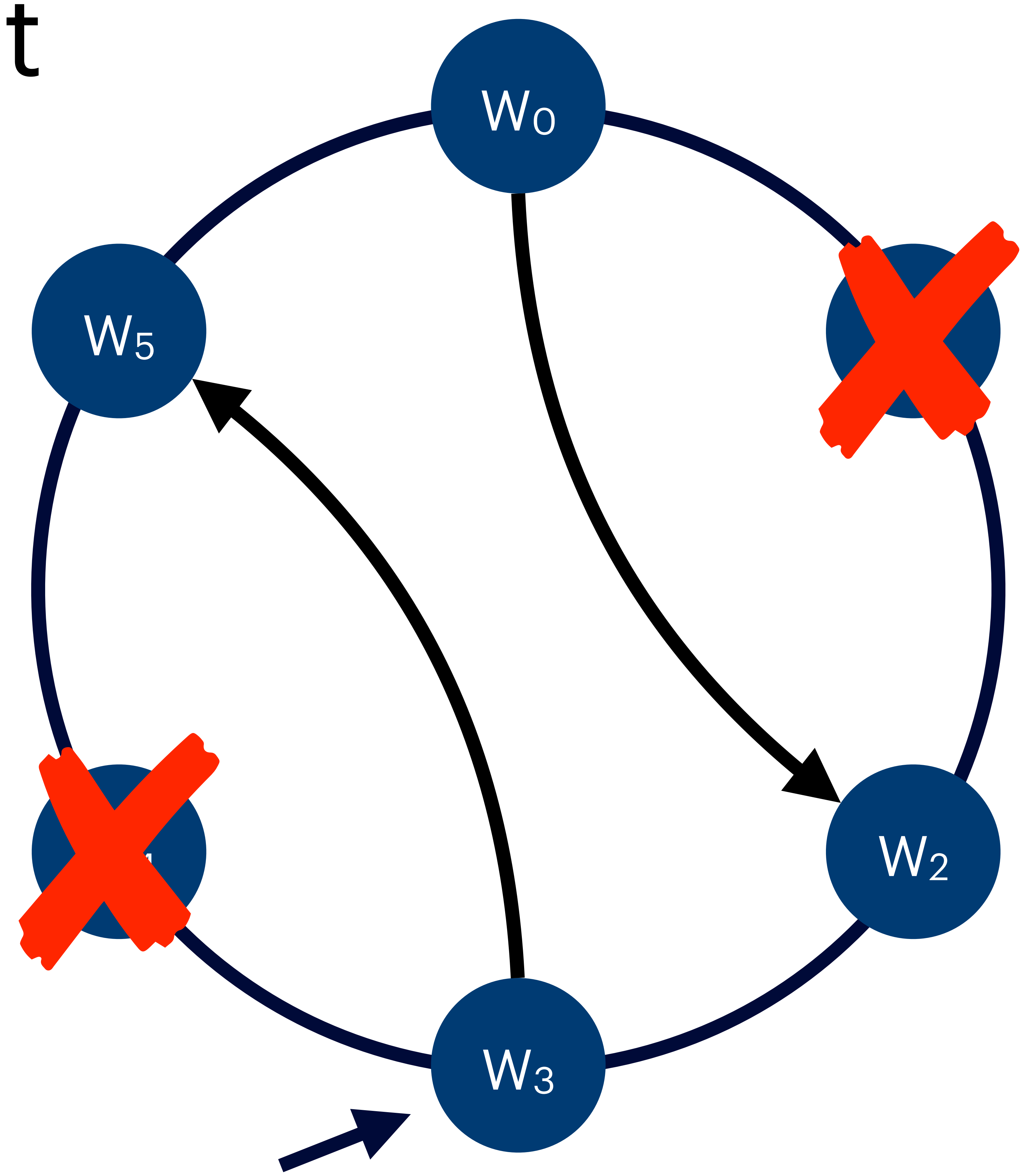
Revocation recovery algorithm

Repairing a broken all-reduce ring

Accept



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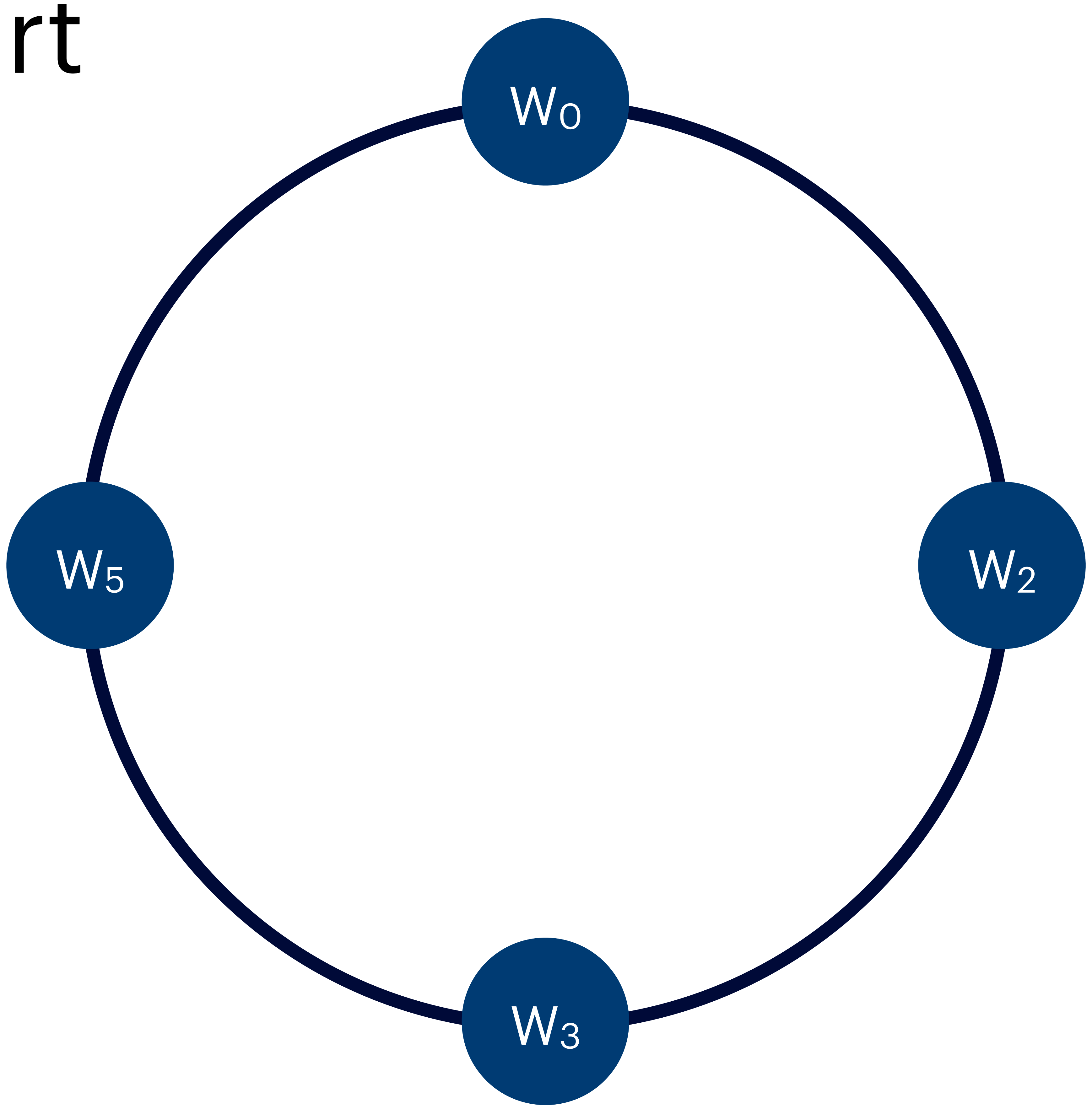
Revocation recovery algorithm

Repairing a broken all-reduce ring

Restart



Worker	Membership
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Challenges	Solutions
Workers become available or get revoked	**Reuse communication channels** for synchronisation to repair the cluster
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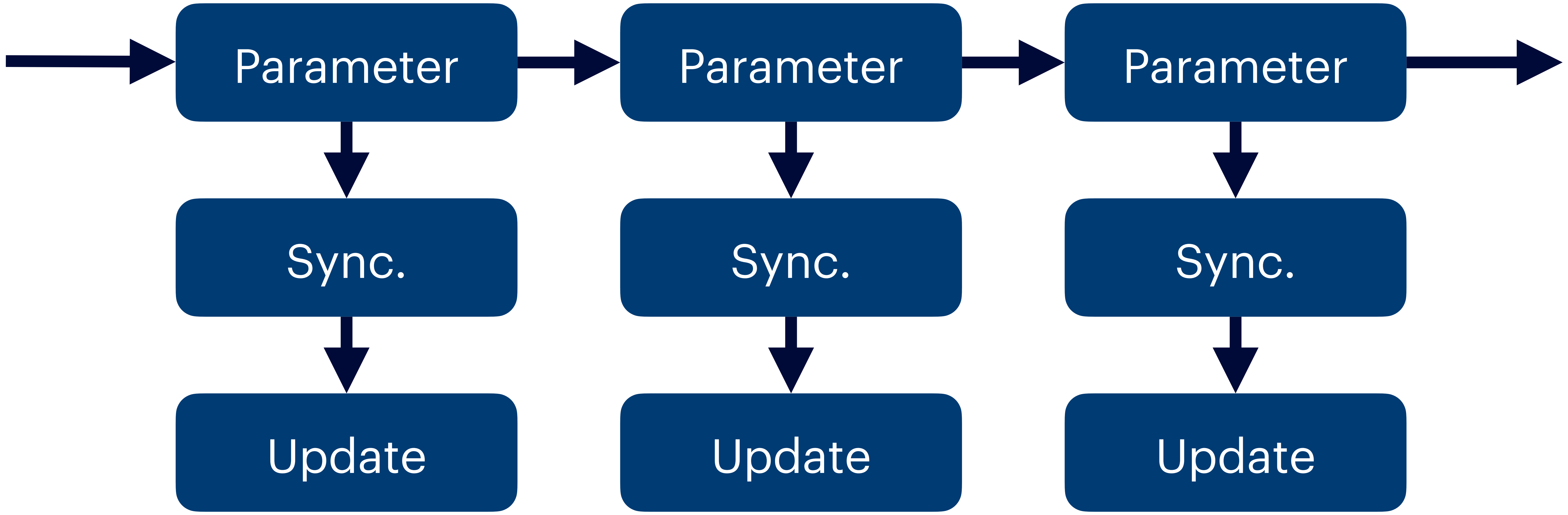
Atomic worker state update

- Pipelined synchronisation



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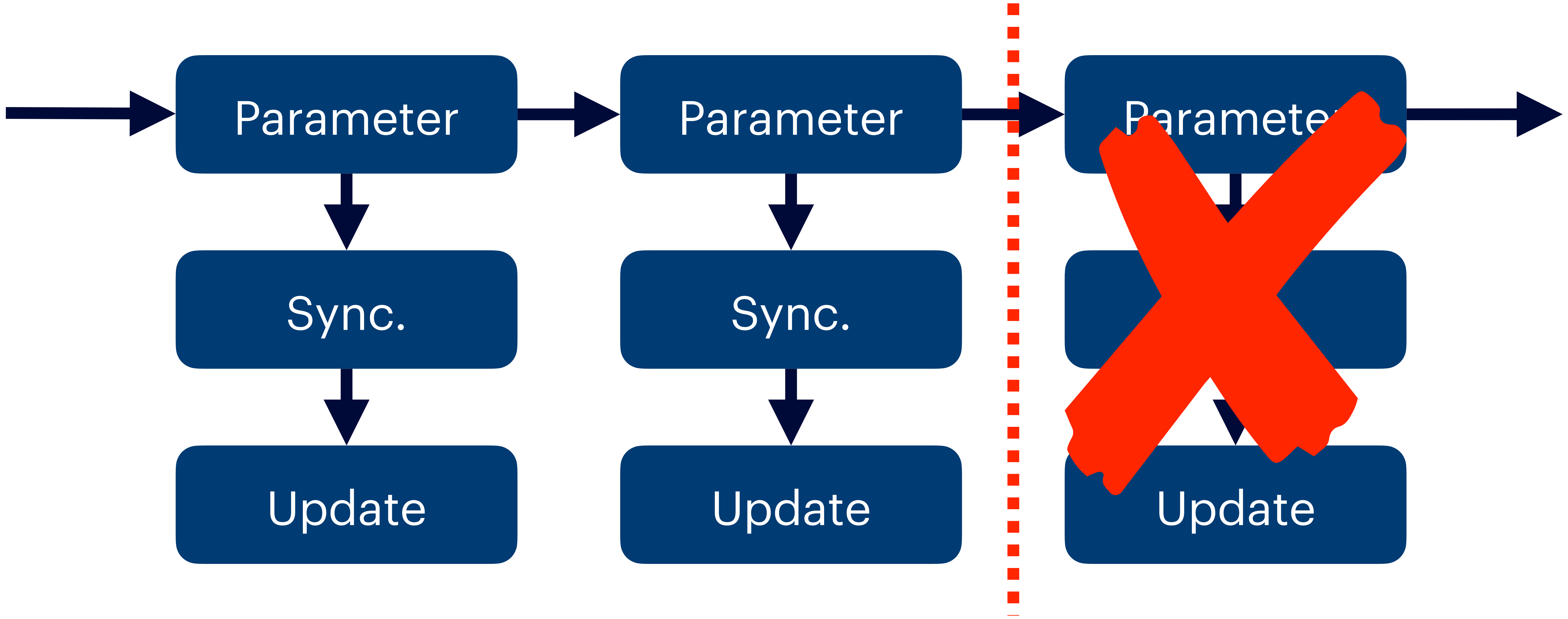
Atomic worker state update

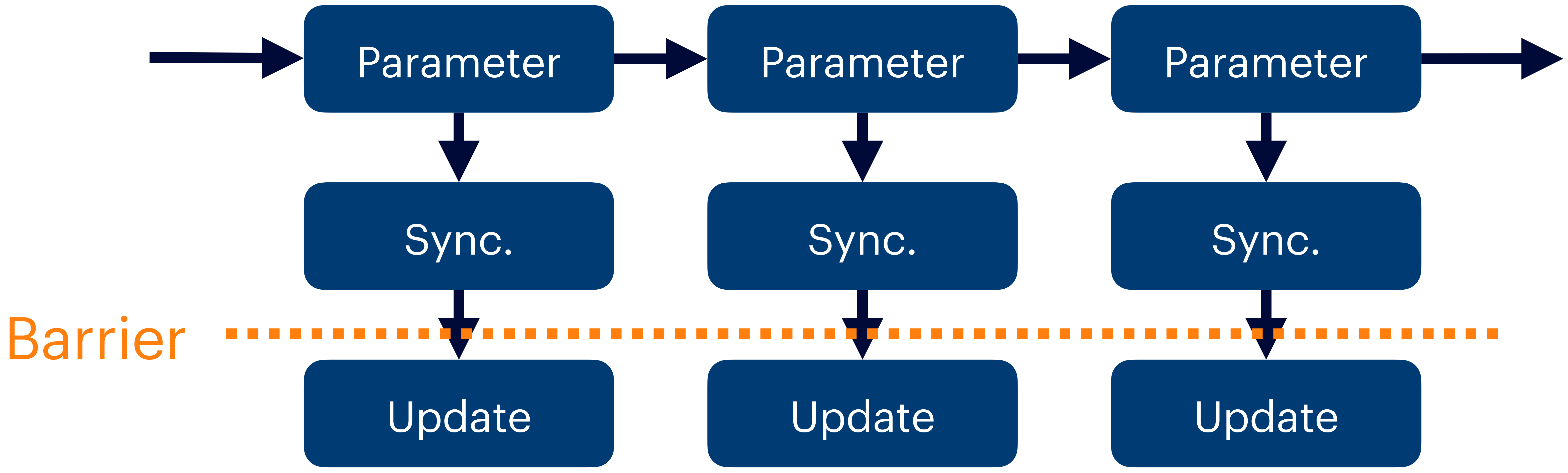
- Pipelined synchronisation
- Revocations can happen meanwhile

→ Partial update leads to inconsistency



Atomic worker state update

- Atomicity: Wait for all synchronisation communications to finish
- Discard updates if communication fails



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Adaptive synchronisation strategies

- Support a range of synchronisation primitives
  - collective and point-to-point synchronisation
- Monitor a metric
  - Number of workers

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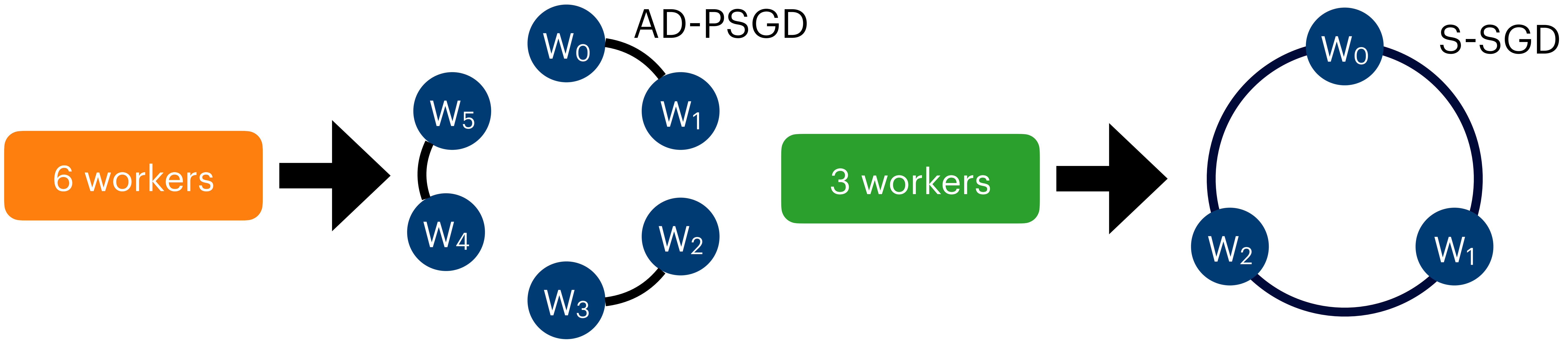
- Support a range of synchronisation primitives
  - collective and point-to-point synchronisation
- Monitor a metric
  - Number of workers
- Define a policy in the beginning
  - When to choose which sync strategy



Evaluation

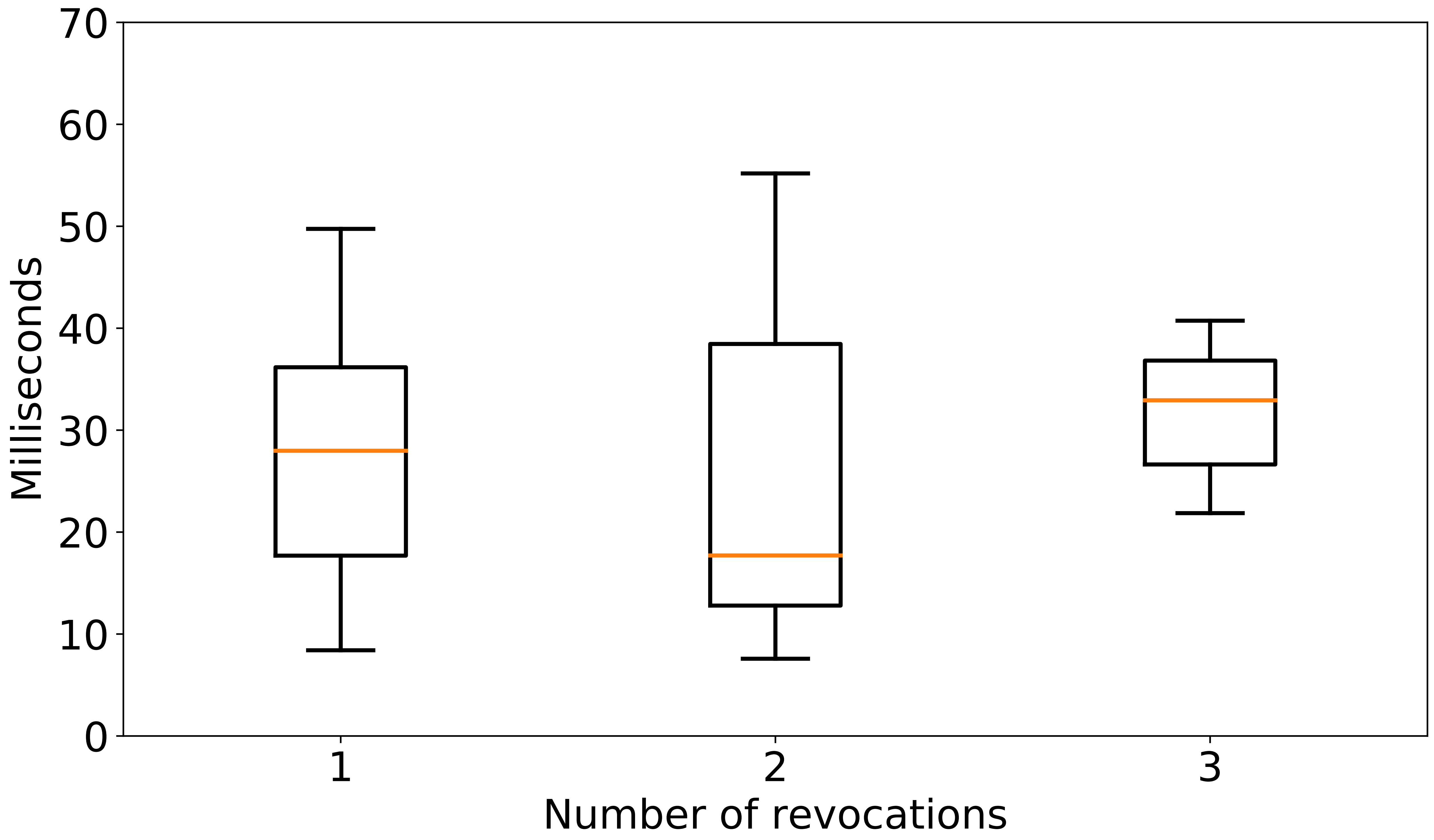
How does the recovery latency change with increasing number of revocations?

Cluster
- 16 workers

Hardware
- Azure NC6 VMs
  - Nvidia K80

Software
- KungFu 0.2.1
- Tensorflow 1.15

ML
- ResNet50
- ImageNet



No significant increase of recovery latency if the number of revocation increases

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Evaluation

How much does the training slow down if we use atomic worker state updates?

Cluster
- 32 workers

Hardware
- Azure NC6 VMs
  - Nvidia K80

Software
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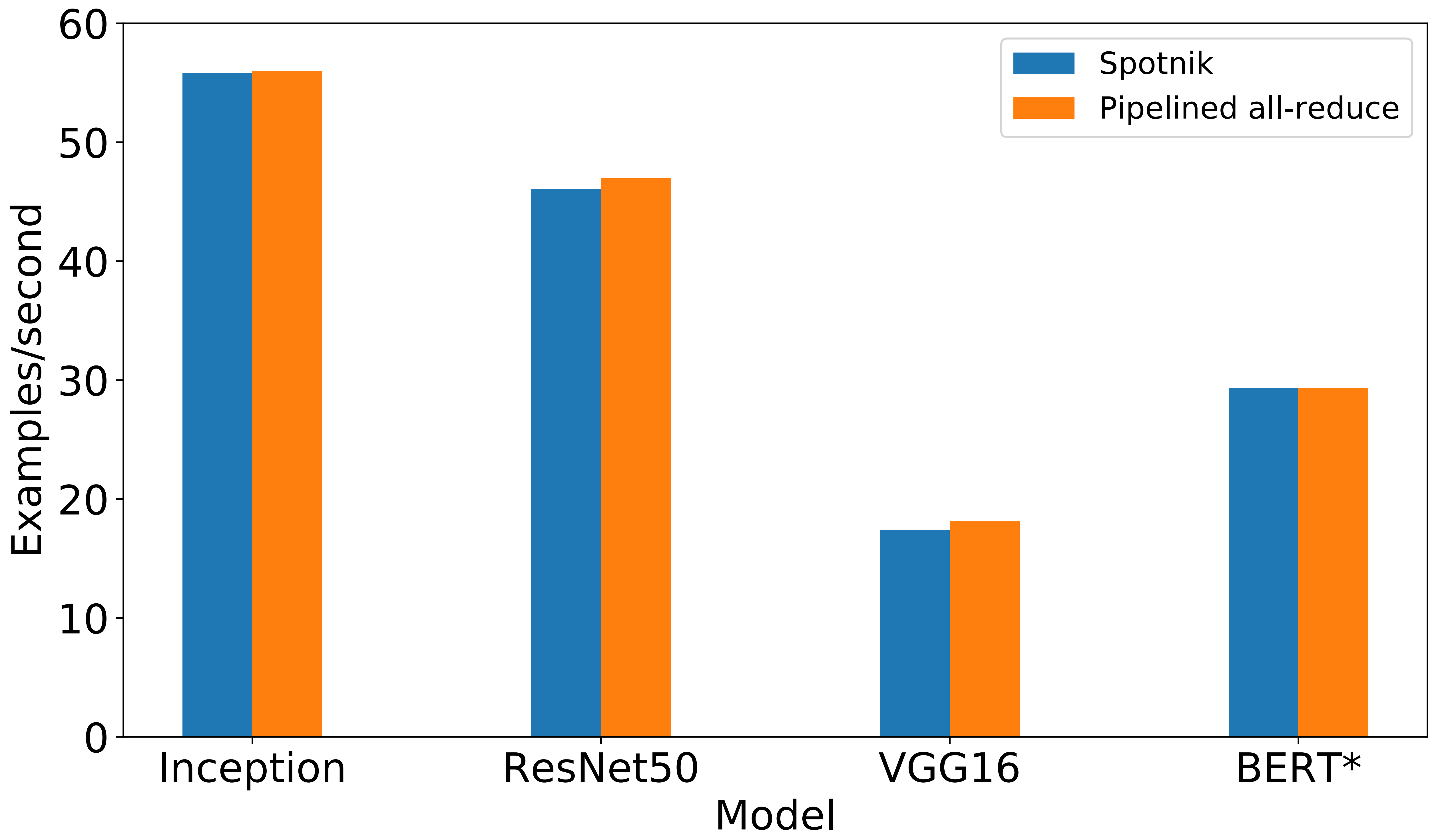

*different Setup

Cluster
- 16 workers

Hardware
- Huawei ModelArts
  - Nvidia V100
  - InfiniBand

Software
- KungFu 0.2.1
- Tensorflow 1.12

Throughput decrease is small

Evaluation

How does the throughput change, if the cluster changes?

Cluster
- up to 32 workers

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- Azure NC6 VMs
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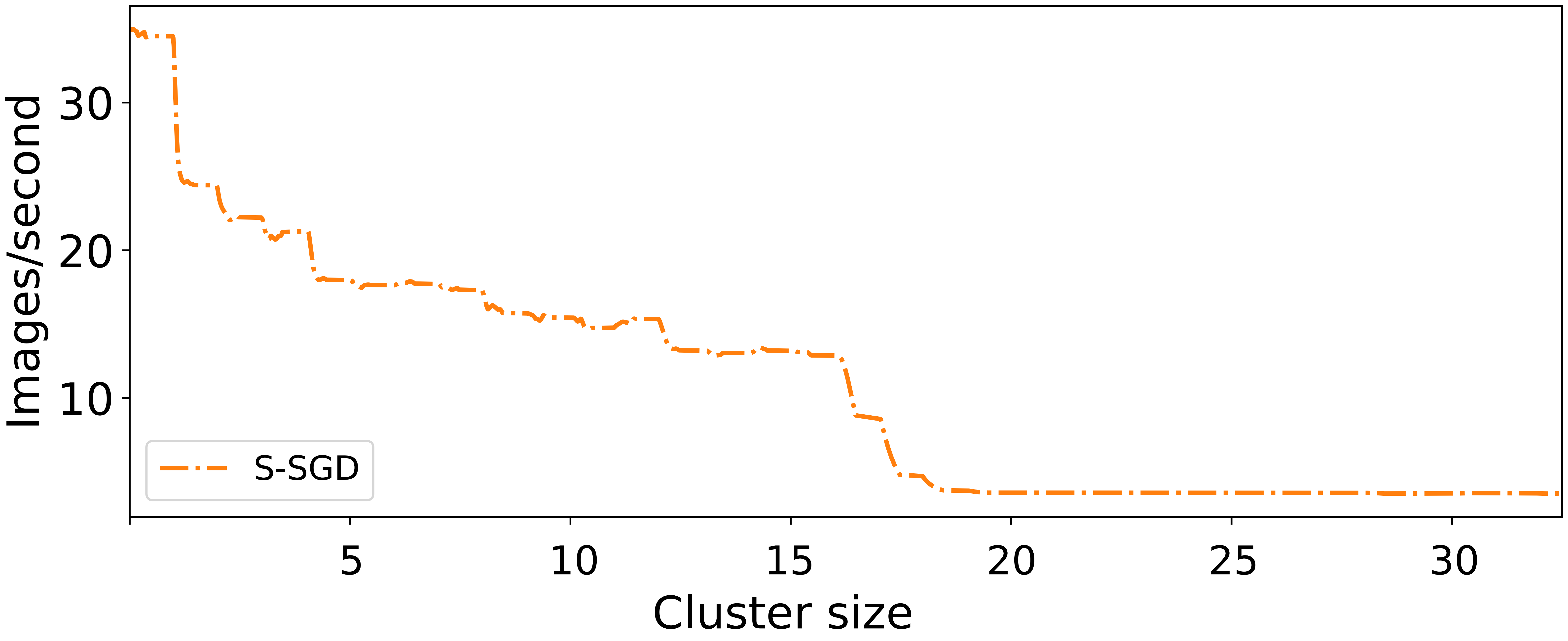

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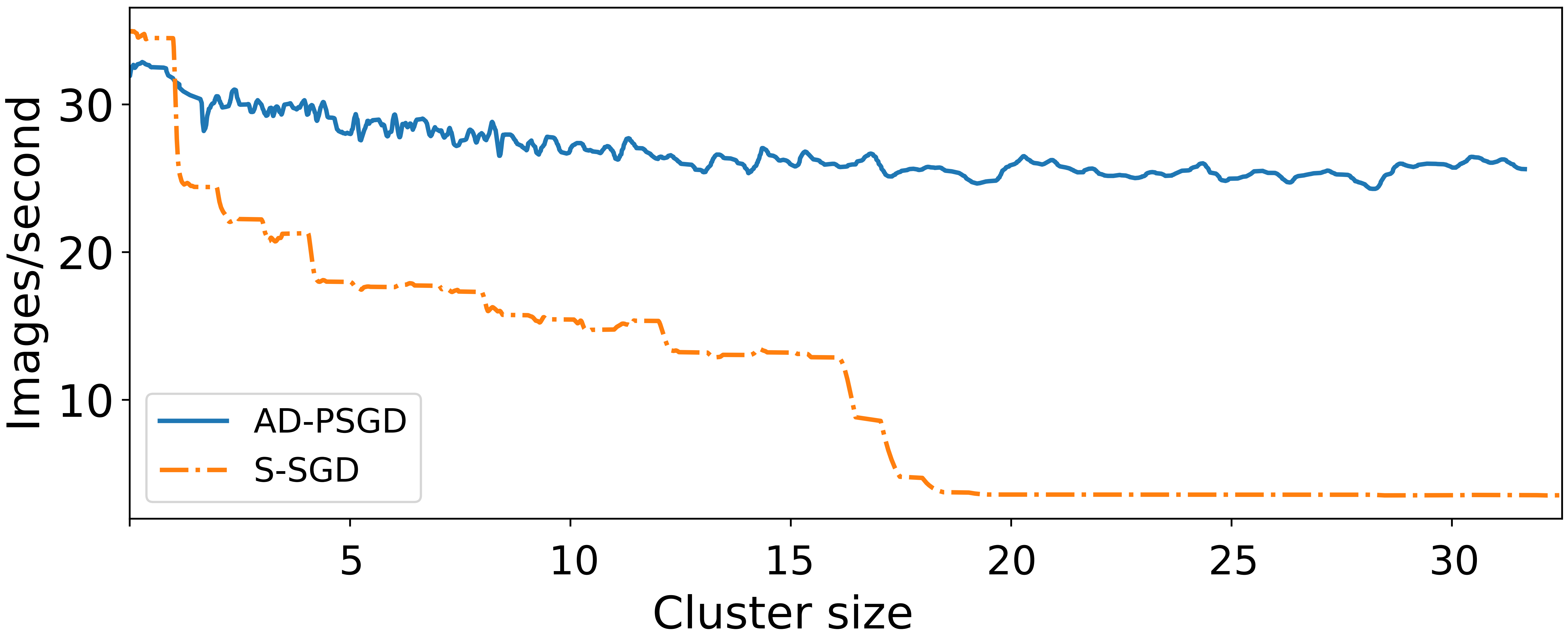

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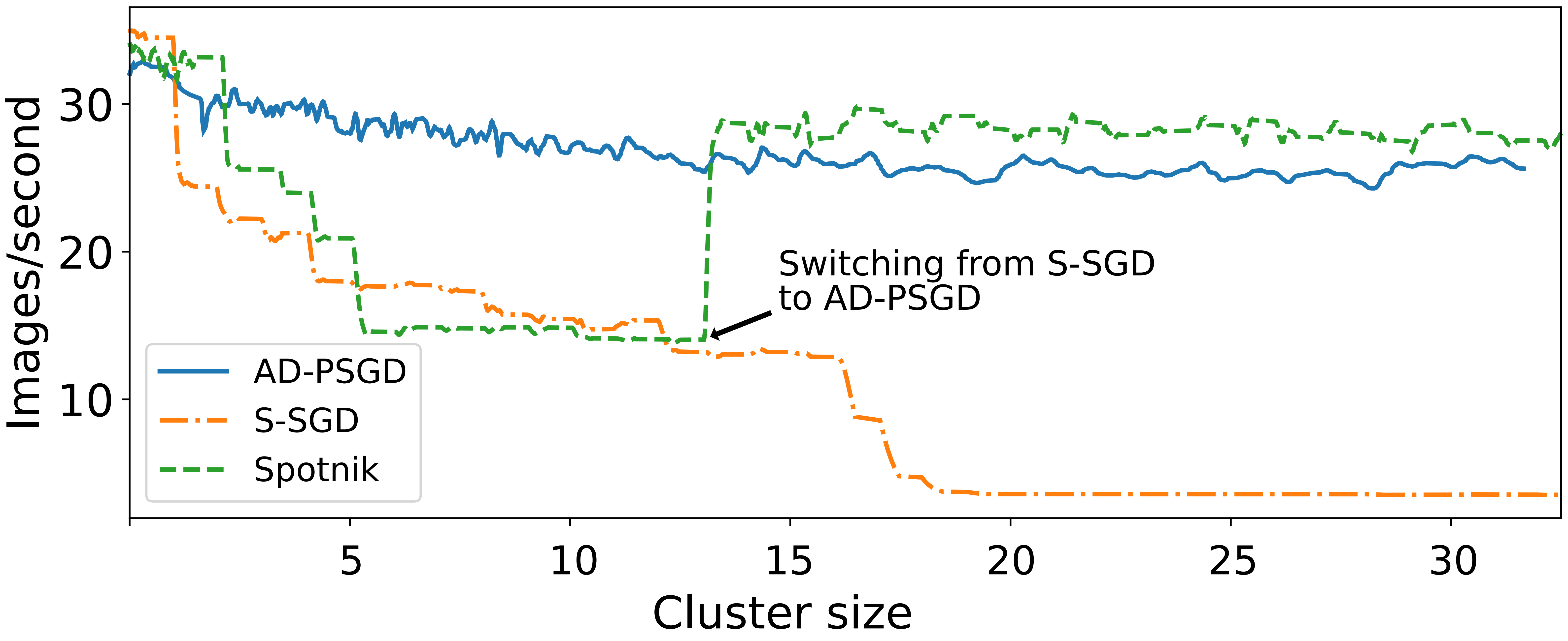

Changing clusters need adaptation

Conclusion

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- No system that runs exclusively on transient resources and has low overhead

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KungFu github.com/lsds/KungFu

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KungFu github.com/lsds/KungFu

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